Wheelchair Skills tests: a systematic review

Kilkens, O.J.E.; Post, M.W.M.; Seelen, H.A.M.; Dallmeijer, A.J.; van der Woude, L.H.V.

published in
Clinical Rehabilitation
2003

DOI (link to publisher)
10.1191/0269215503cr633oa

document version
Publisher's PDF, also known as Version of record

Wheelchair skills tests: a systematic review

Olga JE Kilkens, Marcel WM Post, Annet J Dallmeijer, Henk AM Seelen and Lucas HV van der Woude

Clin Rehabil 2003 17: 418
DOI: 10.1191/0269215503cr633oa

Clinical Rehabilitation 2003; **17**: 418–430

Wheelchair skills tests: a systematic review

Olga JE Kilkens, Marcel WM Post iRv, Institute for Rehabilitation Research, Hoensbroek, **Annet J Dallmeijer** Institute for Fundamental and Clinical Human Movement Sciences, Faculty of Human Movement Sciences, Vrije Universiteit, Amsterdam, **Henk AM Seelen** iRv, Institute for Rehabilitation Research, Hoensbroek and Rehabilitation Foundation Limburg, Hoensbroek and **Lucas HV van der Woude** Institute for Fundamental and Clinical Human Movement Sciences, Faculty of Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands

Received 11th May 2002; returned for revisions 11th November 2002; revised manuscript accepted 14th December 2002.

Objective: To describe and compare the content, feasibility, outcome parameters, and clinimetric properties of the manual wheelchair skills tests reported in the literature.
Design: A systematic literature search was conducted in MEDLINE, EMBASE, PsychINFO and Current Contents. Tests were selected if they were observational tests, designed for subjects using hand-rim wheelchairs and were intended to assess wheelchair skill performance at the activity level.
Results: The search resulted in 34 papers, in which 24 different wheelchair skills tests were described. The skill most frequently included was wheelchair propulsion, consecutively followed by transferring, negotiating kerbs, ascending slopes, traversing tracks, sprinting and performing a wheelie. The three most frequently used outcome parameters were task performance time, independency of task performance, and physical strain during skill performance. Sensitivity to change was evaluated in three tests, validity in 10 tests, and reliability in nine tests.
Conclusions: Many tests are applied to measure wheelchair skill performance using different tasks and outcome measures. This makes it difficult to compare study results. Consensus among researchers as to which skills must be included as well as to standardization of the use of measurement instruments will reduce this problem and will additionally lead to a better insight in the quality of tests.

Introduction

The achievement of independent mobility is vital in the rehabilitation of physically disabled individuals. When ambulation is impaired, a hand-rim wheelchair provides a relatively fast and effective means of mobility for people with lower limb disabilities. A hand-rim wheelchair can provide the necessary access to social, vocational and recreational activities that are conditional to a productive and rewarding life. To function independently, people who use manual wheelchairs for mobility must possess a variety of skills. The ability to propel their wheelchairs over even surfaces brings the freedom to move about within a wheelchair-accessible environment. Independent

Address for correspondence: Olga Kilkens, Institute for Rehabilitation Research, PO Box 192, 6430 AD Hoensbroek, The Netherlands. e-mail: olga.kilkens@irv.nl

10.1191/0269215503cr633oa

mobility within a greater variety of environments requires obstacle negotiation skills. These skills can make the difference between dependence and independence in daily life.[1,2]

Assessment of wheelchair skills can provide useful information concerning a person's current wheelchair skill performance. In clinical situations, wheelchair skills tests can help to define rehabilitation goals concerning mobility, and can also be used to evaluate the progression made regarding wheelchair mobility during rehabilitation. In research settings, measurement of wheelchair skills can be used to study the effect of an intervention aimed at wheelchair mobility or to study the relation between wheelchair skills and, for example, level of activity and/or participation.

At present there is no systematic overview of wheelchair skills tests available in the literature. It is therefore difficult to decide which test is most suitable in research or in clinical practice.

The objective of this review is to systematically document and describe the content, the target population, the study group, the test feasibility, the outcome parameters and the clinimetric properties of those hand-rim wheelchair skills tests that are currently reported in the literature. Such an overview may make it easier to choose the most suitable test to assess wheelchair skills in both clinical and research settings.

Methods

Search strategy

To locate wheelchair skills tests, a computerized literature search of MEDLINE (1966–2001), EMBASE (1989–2001), PsychINFO (1967–2001) and Current Contents (1998–2001) was conducted. The keywords used were: mobility and wheelchair combined with skill, task, measurement, test, ADL, functional, instrument, performance, clinimetrics, psychometrics, pathology, behaviour, activity, disability and assessment. The search strategy is described in the Appendix. In addition, the references given in relevant publications were further examined. Only studies written in English that were published in scientific journals were taken into consideration.

Selection criteria

A test was selected if it was an observational test,[3] if it was constructed for subjects using hand-rim wheelchairs and when it intended to assess wheelchair-assisted mobility skills at the activity level as described in terms of the International Classificiation of Functioning, Disability and Health (ICF).[4] In the ICF, mobility is defined as: 'moving by changing body position or location or by transferring from one place to another'. Consequently, this review focuses on tests that aim to assess the ability to propel and manoeuvre a wheelchair under standardized and/or simulated conditions of daily living. Tests aimed at measuring physical capacity were not selected.

The first author performed the selection of the tests, by reading the abstracts of all the initially identified articles. When necessary the full article was obtained and studied. In case of doubt on selection of a test, the other authors were consulted.

Assessment of selected tests

The wheelchair skills tests were systematically described and compared with respect to the following aspects:

- Content: the skills included in the test.
- Target population: the diagnostic groups for which the test was developed.
- Population at study: the diagnostic groups in which the test was used or studied.
- Feasibility: the amount of time and equipment needed to perform the test.
- Test outcomes: the outcome parameters used to reflect wheelchair skill performance and the complexity and interpretation of the scoring method.
- Clinimetric properties: sensitivity to change, validity and reliability of the test.

Results

Selection of tests

The selection process produced 34 papers in which 24 different wheelchair skills tests were described.[5–38] Table 1 provides an overview of the selected tests, arranged alphabetically, according to the name of the first author of the paper in which the test was mentioned. Of the 24 tests

Table 1 General overview of the selected wheelchair skills tests

Author *Name of test*	*N*	Target population	Study population	Outcomes
Agre[5]	33	No information	Patients with spina bifida	Wheelchair propulsion velocity
Bolin[6]	4	No information	Patients with SCI	Task performance times Physical strain (HRpeak) Subjective rating of performance
Capodaglio[7] Taricco[33,34] *VFM*	8 47, 94	Patients with SCI	Patients with SCI	Independency of task performance
Dallmeijer[8,9]	20, 19	No information	Patients with SCI	Task performance times Physical strain (%HRR)
Duffill[10]	17	No information	Patients with SCI	Ability to perform tasks
Dunkerley[11]	11	No information	Patients with SCI	Task performance times
Durán[12]	13	No information	Patients with SCI	Task performance times Ability to perform tasks
Findley[13]	40	No information	Patients with spina bifida, healthy individuals	Wheelchair propulsion velocity
Gans[14]	40	No information	Patients with muscoloskeletal and neuromuscular disorders	Task performance times
Haley[16,17] *TAMP*	206, 206			Independency of task performance Technique Movement pattern Movement control and co-ordination
Gouvier[15] Webster[36–38] *WOC*	2 72, 87, 55	Patients with stroke	Patients with stroke, healthy individuals	Number of collision errors
Harvey[18]	20	No information	Patients with SCI	Independency of task performance
Hutzler[19]	9	Wheelchair athletes	Wheelchair basketball players with poliomyelitis, SCI, and amputation	Task performance times Distance covered
Janssen[20]	37	No information	Patients with SCI	Task performance times Physical strain (HRpeak, HRmean)
Janssen[21]	44	No information	Patients with SCI	Physical strain (%HRR)
Janssen[22]	37	No information	Patients with SCI	Physical strain (%HRR)
Jebsen[23]	118	No information	Patients with stroke, amputations, SCI neuropathy, hip fractures and healthy individuals	Task performance times

Kirby[24]	42	No information	Patients with SCI, amputations and healthy individuals	Task performance times Perceived task difficulty Safety of skill performance % subjects able to learn skill
Kirby[25] *WST*	24	No information	Patients with stroke, amputations, SCI, musculoskeletal and neuromuscular disorders	Ability to perform tasks
Lehmann[26]	12	No information	Patients with SCI	Distance covered Maximum angle of inclination of slopes
Mattison[27]	26	No information	Patients with stroke, vascular diseases and healthy individuals	Task performance time Distance covered Physical strain (HRpeak, physiological cost) Perceived exertion during test performance
Mizukami[28]	109	No information	Patients with SCI	Independency of task performance
Panikoff[29]	80	No information	Patients with head injury	Independency of task performance
Schnelle[30,31]	97, 76	No information	Nursing home residents	Maximum propulsion endurance time
Simmons[32]	65			Independency of task performance Maximal wheeling distance Wheelchair propulsion velocity
Vanlandewijck[35]	46	Wheelchair athletes	Wheelchair basketball players with spina bifida, SCI, spastic diplegia, polio, amputations and healthy individuals	Task performance time Distance covered Wheelchair propulsion velocity

SCI, Spinal cord injury; VFM, Valutazione Funzionale Mielolesie; TAMP, Tufts Assessment of Motor Performance; WOC, Wheelchair Obstacle Course; WST, Wheelchair Skills Test; HRpeak, peak heart rate reached during task performance; %HRR, percentage heart rate reserve; HRmean, mean heart rate reached during task performance.

found, seven were presented as measurement instruments and were extensively described in terms of development, content and use.[7,14,18,23,25,35,36] In all other papers the aim was to evaluate an intervention or to detect differences between groups. These tests were only briefly described in the Methods section of the article. Only four tests had been given a name: the Valutazione Funzionale Mielolesie (VFM),[7] Tufts Assessment of Motor Performance (TAMP),[14] the Wheelchair Skills Test (WST)[25] and the Wheelchair Obstacle Course (WOC).[36]

Assessment of selected tests

Content of tests

Table 2 displays the types of wheelchair skills included in the different tests. Wheelchair propulsion is the most frequently included skill (in 14 tests). It is assessed in different ways: a set period of time,[6,19] a fixed distance[5,6,14,18,25,36] or the longest distance possible.[30,35] Following wheelchair propulsion, transfer from and to the wheelchair is the most commonly included skill (in 11 tests). Most tests require the performance of several different transfers.[7,14,18,20–23,28,29] The negotiation of kerbs, ascending slopes and traversing tracks are third in line of most frequently used skills (each in 10 tests). The height of the kerbs used ranged from 0.025 to 0.15 m. Two tests[7,12] require both ascending and descending of the kerb. All other tests only assess the ascending of the kerb. In all but three tests,[7,10,14] the slopes used are defined in terms of inclination and length, inclinations ranging from 1 to 11 degrees, length ranging from 3.05 to 21 m. Some examples of tracks used are: slalom,[6,19,25] figure of eight[11] and obstacle course.[12,36] In six tests a sprint is included. Nearly all tests use a sprint over a fixed distance (length ranging from 6.5 to 30 m). Although performing a wheelie is an important skill in achieving wheelchair mobility, this skill is only included in four tests.

Eleven tests include, in addition to the skills already mentioned, other specific wheelchair skills, e.g., managing brakes, negotiating doors and loading the wheelchair into a car. Fifteen tests consist entirely of the performance of wheelchair skills. In eight tests wheelchair skills are a part of a broader measure of ADL skills; these tests encompass other ADL tasks such as eating, bed mobility skills and washing hands.[7,8,14,18,21,23,28,29]

Target population and population at study

Although only four tests were designed for a specific target population, 16 tests have only been used in study groups with one specific diagnosis, most often spinal cord injury. Four tests were used for subjects with varying medical conditions (Table 1).

Feasibility

On the one hand, tests should include enough elements to obtain an in-depth insight into wheelchair skill performance; on the other hand, tests have to be efficient and as short as possible. The completion time was mentioned for only six tests. The VFM,[7] the TAMP[14] and the test of Jebsen *et al.*[23] take up to 1 hour to complete. However, these tests contain other ADL tasks as well as specific wheelchair skills. The performance of Harvey's test[18] requires approximately 15 minutes, the time needed to complete the WST[25] is 30 minutes, and the mean test duration of the wheelchair basketball field test of Vanlandewijck *et al.*[35] is 1 hour and 22 minutes.

Ideally, tests should not require much space or special equipment. In most studies, the materials needed for test performance are not addressed. In their paper, Jebsen *et al.*[23] dedicated a section to test equipment (a hospital bed, standardized wheelchair and straight chair). Harvey *et al.*[18] stated that no special equipment is required to perform their test. To assess physical strain during wheelchair skill performance a heart rate monitor is required. Twelve studies provide information on the wheelchairs used during test performance.[6,8,11–13,20–26] Three studies used standardized wheelchairs.[23,24,26] In eight studies, subjects used their daily use wheelchairs.[8,11–13,20–22,25] Bolin *et al.*[6] aimed to improve the individual fit of the wheelchair in their subjects. The subjects performed a wheelchair skills test twice: first in their daily use wheelchair and later in an adapted or new wheelchair.

The outcome measures of the different tests are displayed in Table 1. The most common outcome measure is task performance time. Independence in wheelchair skill performance is

Table 2 Content of wheelchair skills tests

Author	Propulsion	Sprint	Kerb	Slope	Wheelie	Transfer	Track	Other wheelchair skills
Agre[5]	+	+						
Bolin[6]	+		+	+			+	
Capodaglio[7]; Taricco[32,33]	+		+	+	+	+	+	+
Dallmeijer[8,9]				+		+		+
Duffill[10]	+		+	+			+	+
Dunkerley[11]		+					+	
Durán[12]			+	+	+		+	+
Findley[13]	+	+						
Gans[14]; Haley[16,17]	+			+		+		+
Gouvier[15]; Webster[36–38]							+	
Harvey[18]	+		+	+		+		
Hutzler[19]	+	+					+	
Janssen[20]			+			+		
Janssen[21]			+	+		+		+
Janssen[22]			+			+		
Jebsen[23]		+				+		+
Kirby[24]					+			
Kirby[25]	+		+	+	+	+	+	+
Lehmann[26]	+			+				
Mattison[27]							+	
Mizukami[28]	+					+		+
Panikoff[29]	+		+			+	+	+
Schnelle[30,31]; Simmons[32]	+							
Vanlandewijck[35]	+	+						+

Less common wheelchair skills are noted in the column 'other wheelchair skills'.

assessed by taking into account the use of assistive devices or the amount of help needed from another person. Six tests measure physical strain during skill performance, four tests evaluate distance covered during wheelchair propulsion, four tests rate the velocity of wheelchair propulsion, and three tests assess subjective ratings regarding skill performance.

A test should preferably have an uncomplicated scoring system that is convenient to use and that can be analysed easily. The scoring of the TAMP[14] is extremely complex: one hundred and thirteen skills have to be rated on six measurement dimensions and rating this test requires extensive training.

Clinimetric properties

Nine tests[6,10,11,13,22,24,26,28,30] were not evaluated on any of the clinimetric properties. Three tests provide information on sensitivity to change.[7,8,12] Only two tests, the VFM[7] and the WST,[25] were explicitly subjected to a validation study. For eight other tests[5,12,19,21,24,26,28,30,36] information on validity could be retrieved from the articles. The validity of these tests, however, was not explicitly evaluated. Information concerning reliability was given for 10 tests.[7,14,15,18–20,23,25,27,35] Only five tests[19,23,25,27,36] provided data on both reliability and validity. Table 3 displays the 11 tests from which the sensitivity to change and/or the validity have been evaluated. In Table 4, the 10 tests that have been assessed on the topic of reliability are shown.

From Table 4 it can be seen that all available test–retest and inter-rater reliability figures are satisfactory up to excellent; the data on validity are less unequivocal (Table 3).

Discussion

A literature search resulted in the selection of 24 different wheelchair skills tests. This collection may be incomplete, since only English-written studies, published in scientific journals were taken into account. However, we feel that we have provided a critical and useful overview of tests in which wheelchair skills are assessed.

Table 3 Sensitivity and validity of the selected wheelchair skills tests

Author	Sensitivity to change	Content validity	Construct validity
Agre[5]	No information	No information	Failed to find a relationship between motor function and propulsion speed
Capodaglio[7] Taricco[33, 34]	Two groups were tested before and after a 6-week rehabilitation programme: conventional or enhanced. No significant differences between the groups[7] Subjects were tested at the start and the end of their rehablitation period. Scores had significantly improved for subjects with quadriplegia and high-level paraplegia. There were no changes in the scores of subjects with low-level paraplegia[33]	The content of the VFM was compared to the content of the FIM, Barthel index and QIF. The VFM includes all basic ADL domains and has the largest number of tasks in the domains transfers and wheelchair use which are particularly relevant for wheelchair-dependent people[33]	No information
Dallmeijer[8,9]	Subjects were tested at the start and at the end of their rehabiliation period. There were no changes in physical strain during the slope ascend and the transfers. The performance time of the slope ascend significantly decreased. The performance time of the transfer did not change[9]	No information	No information
Durán[12]	Subjects were tested before and after a 16-week exercise programme. Task performance times significantly decreased. The ability to negotiate kerbs improved	No information	Mean FIM scores were associated with an improved ability to negotiate kerbs, and inversely associated with task performance times
Gouvier[15] Webster[36-38]	No information	No information	Right-sided stroke patients with neglect hit significantly more objects in left- than in right-space, and made significantly more errors than stroke patients without neglect and healthy control subjects[36,37]
Hutzler[19]	No information	No information	Inverse correlation between sprint performance time and the subjects' wheelchair basketball classification ($r_{spearman}$=−0.64). No relation between body weight and task performance times
Janssen[21]	No information	No information	A lower lesion level was associated with a lower level of physical strain during wheelchair skill performance. No relation between lesion-completeness and physical strain during skill performance. Physical strain during skill performance was inversely related to strength, sprint power, peak oxygen uptake, and maximum power output ($r_{pearson}$=−0.41 to −0.73)

Jebsen[23]	No information	No information	Healthy people performed the tasks concerning wheelchair mobility faster than patients with mobility problems
Kirby[25]	No information	Occupational therapists evaluated the content of the WST, and unanimously approved with 30 of the 33 skills	Occupational therapists rated whether patients' wheelchair skills had improved, not changed or worsened between two test trials. They rated that 13 subjects had improved, 8 had not changed, and none had worsened. Accordingly, the mean improvement in the total score was larger for the 'improved subjects' than for the 'unchanged subjects'. OT's also completed a VAS reflecting the subjects' wheelchair skill performance. Mean improvement for the 'improved subjects' was significantly higher than for the 'unchanged subjects'. Test scores significantly related to age, and wheelchair experience. No relation was found between test scores and diagnosis
Mattison[27]	No information	No information	There was no relation between physical strain during skill performance and age or diagnosis. Physical strain was significantly related to the perceived exertion during test performance ($r_{pearson}$=0.84)
Panikoff[29]	No information	No information	A significant relation between the ability to perform transfers and length of coma

FIM, Functional Independence Measure; QIF, Quadriplegia Index of Function.

> **Clinical messages**
>
> - A large number of wheelchair skills tests have been described in the literature.
> - It is recommended to use only those tests that have been tested and shown to be adequate in terms of responsiveness, validity and reliability.
> - Future research should focus on further validation of existing tests instead of developing more tests.

Content of tests

There is limited consensus as to the content of wheelchair skills tests (Table 2). Even skills frequently used in tests (wheelchair propulsion, transfer, kerb, slope) show a large variation in, for instance, driving distance, objects to transfer to, height of the kerbs and angle of inclination of slopes. The number of skills included in wheelchair skills tests also shows a large variation, ranging from one[36] to 113.[14] More research is needed to identify a limited number of skills that together best reflect wheelchair skill performance in people who dependent on a manual wheelchair for their mobility.

Target population and population at study

Although just four tests were designed for a specific target group, 16 tests were only used in a specific group (Table 1). The latter tests might also be capable of assessing wheelchair skills in subjects with other characteristics, but further research on validation and reliability in other subject groups is necessary to test this expectation.

Test outcomes

Many different outcome parameters are used in the selected tests (Table 1). The choice for a particular outcome measure depends on the objectives of the study. Tests can be used to determine the feasibility of manual wheelchair propulsion, to measure the level of independence in wheelchair ADL, or to evaluate the effects of interventions. Outcome measurements in the categories time, distance and physical strain are very useful to provide information on the practicability of manual wheelchair mobility in daily life. When a subject needs, for example, five minutes to propel his or her wheelchair over a distance of 50 metres, an electric wheelchair may be a more suitable means of mobility. If the goal of a study is to describe the level of independent mobility, a scale of independence in performing wheelchair tasks is an obvious outcome measure.

The level of independence in performing well-chosen wheelchair skills is expected to be directly related to independent mobility in daily life. People who cannot perform wheelchair skills independently will not achieve independent mobility in all environmental circumstances. For the assessment of (changes in) wheelchair skill performance in completely independent individuals, outcome measures such as time, distance and physical strain should be applied. This is also shown by the results of Taricco *et al.*[34] who measured wheelchair skill performance using a scale of independence. They showed good sensitivity to change in subjects with high-level spinal cord injury, but no sensitivity to change in subjects with low-level spinal cord injury.

Other outcome measures are relevant, but not so easy to interpret. The test of Dallmeijer *et al.*[8,9] evaluates both physical strain during wheelchair skill performance and performance time of each skill. These two parameters are, however, interdependent. A decrease in performance time, reflecting better test performance, may result in a higher level of physical strain, indicating worse test performance. This interdependency may obfuscate the interpretation of test results.

Further, wheelchair skill performance relies on both technique and physical capacity. Repeated measurements can, for instance, show that maximal wheeling endurance time has increased over a certain period, which may be the result of an increase in physical capacity, an improved technique resulting in higher mechanical efficiency of wheelchair propulsion, or a result of both. For a correct interpretation of changed outcomes in longitudinal studies, the performance of a wheelchair skills test is best combined with an exercise test that provides information about physical capacity.

The WST[25] leads to one overall score of wheelchair skill performance, expressed as the sum of the scores obtained on each skill. Such a total score might be very useful for research purposes,

Table 4 Reliability of the selected wheelchair skills tests

Author	Test–retest reliability	Inter-rater reliability	Intra-rater reliability
Capodaglio[7] Taricco[33, 34]	No information	The inter-rater reliability of the VFM was demonstrated in previous studies. These studies were only published in Italian and were therefore not retrieved	No information
Gans[14] Haley[16,17]	No information	Subjects' test performances were videotaped, and independently evaluated by three raters. Regarding wheelchair skills, inter-rater reliability was excellent (kappa = 0.65–0.83)[13]	No information
Gouvier[15] Webster[36-38]	No information	Two raters scored the number and type of errors two subjects made during test performance. Their agreement on the occurrence of errors and the type of error made was successively 95% and 83%[14]. Two raters scored the tests. They agreed 100% on the occurrence of errors, 80–90% on the occurrence of direct hits ($r_{pearson}$=0.90-0.97), and 85–90% on the occurrence of sideswipes errors ($r_{pearson}$=0.92–0.95)[35]	No information
Harvey[18]	No information	Two raters scored the test performances resulting in high inter-rater reliability (kappa=0.82–0.98)	No information
Hutzler[19]	Excellent test–retest reliability for task performance time and propelled distance ($r_{spearman}$=0.87–0.99) on two test performances	No information	No information
Janssen[20]	Subjects performed three test trials: two on the same day (trial 1 and 2) and one a week later (trial 3). Correlations for heart rate were good for trial 1 versus 2, and trial 1 versus 3 (1 vs 2: $r_{pearson}$=0.79–0.97, ICC=0.73–0.97, 1 vs 3: $r_{pearson}$=0.69–0.95, ICC=0.52–0.92). Good correlations for the performance time of the kerb ascend for trial 1 versus 2 ($r_{pearson}$=0.88, ICC=0.82). Low correlations for trial 1 versus 3 ($r_{pearson}$=0.31, ICC=0.20)	No information	No information
Jebsen[23]	Performance times correlations were excellent ($r_{pearson}$=0.85–0.99)	No information	No information
Kirby[25]	Good correlation between the scores on two different test occasions ($r_{spearman}$=0.65)	Two raters independently scored the same **videotapes** of test performances, resulting in an excellent correlation coefficient ($r_{spearman}$=0.95)	One rater scored the same videotapes of subjects test performances twice, resulting in an excellent correlation coefficient ($r_{spearman}$=0.96)
Mattison[27]	Subjects performed two test trials. Good correlations for distance traveled, physical strain during wheelchair propulsion, and propulsion velocity ($r_{pearson}$=0.96, 0.84, and 0.70)	No information	No information
Vanlandewijck[35]	Excellent correlations for all tasks ($r_{spearman}$=0.80–0.97), only one being good ($r_{spearman}$=0.65)	No information	No information

but can only lead to valid information if all test items measure the same phenomenon. The authors did not assess this.

Clinimetric properties

Clinimetric properties of nine tests were not described at all. Only two tests: the VFM[7] and the WST[25] have been extensively validated. The WST is the only test that has been adequately tested on both validity and reliability. More research is needed to assess the clinimetric qualities of the other tests described in the current review before these tests can be recommended for use. Performance time and physical strain are outcome measures that can be measured objectively. Ordinal scales of dependence, frequently used in wheelchair skills tests, are subject to interpretation. Raters need to assess the amount of help, often expressed in a few number of categories of assistance needed. Therefore, the raters should receive appropriate training. The good inter-rater reliability figures of tests using ratings of independence are promising, but these figures are, in part, obtained in very small study groups. Although also rarely investigated, test–retest analyses of time, distance, velocity and physical strain revealed satisfying results.

The measurement of wheelchair skills will, at least in part, support validity of the tests due to the close resemblance with daily life activities. However the choice of tested tasks, outcome measures and the applicability in different subject groups may influence validity. One aspect of validity that is often ignored is the influence of wheelchair configuration on wheelchair skill performance outcomes. Subjects will perform best in a wheelchair that is optimally adjusted to their personal characteristics. To ensure that variations in wheelchair skill performance were not due to changes in wheelchair configuration, some tests were performed in standardized wheelchairs.[23,24,26] However, most tests were executed in daily use wheelchairs.[8,12,20,22,25] This may have resulted in subjects using different wheelchairs on different test occasions, which may have affected sensitivity to change and test–retest reliability or may bias comparisons between subjects having wheelchairs of different quality. Use of the daily use wheelchair may, however, improve the validity of the test. Subjects are not troubled by an unfamiliar wheelchair, and their test results will be more representative for their wheelchair skill performance in daily life. Therefore a careful choice for, or against standardization of wheelchair configuration has to be made, dependent on the purpose and the design of the study.

In conclusion, this review shows that there is, as yet, no standard test to measure wheelchair skill performance. Only seven out of the 24 tests found were extensively described in terms of development, content and use[7,14,18,23,25,35,36] and only two tests have been extensively validated.[7,25]

In addition, most tests have only been used in one study. Without further research on validity and reliability, these tests should be used with caution. The use of many different tests makes it difficult, if not impossible, to compare study results. Standardization of the skills tested and the use of measurement instruments are needed to enable comparisons between studies and to give a better insight in the quality of the tests used.

Future research could best concentrate on further validation of existing tests instead of developing even more tests. The selection of the best and most relevant items of these tests and combining elements of various tests might eventually lead to a superior test. However, it might not be possible to compose the ideal test for all patient groups and purposes. A distinction between a clinical instrument (containing all relevant items for assessment and evaluation of individual treatment) and a research instrument (containing a selection of items of varying difficulty) might be useful.

Acknowledgements

The study was supported by the Dutch Health Research and Development Council, ZON-MW, Rehabilitation program, grant no. 1435.0003.

References

1 Somers M. *Spinal cord injury, functional rehabilitation*. Connecticut: Appleton & Lange, 1992.
2 Britell CW. Wheelchair prescription. In: Lehmann JF, Kottke FJ eds. *Krusen's handbook of physical medicine and rehabilitation*, fourth edition. Philadelphia: WB Saunders, 1990: 548–63.
3 Bussmann JBJ, Stam HJ. Techniques for measurement and assessment of mobility in rehabilitation: a

theoretical approach. *Clin Rehabil* 1998; **12**: 455–64.
4 WHO. *International Classification of Functioning, Disability and Health*. ICIDH-2 final draft. Geneva: WHO, 2001.
5 Agre JC, Findley TW, McNally MC *et al*. Physical activity capacity in children with myelomeningocele. *Arch Phys Med Rehabil* 1987; **68**: 372–77.
6 Bolin I, Bodin P, Kreuter M. Sitting position – posture and performance in C5–C6 tetraplegia. *Spinal Cord* 2000; **38**: 425–34.
7 Capodaglio P, Grilli C, Bazzini G. Tolerable exercise intensity in the early rehabilitation of paraplegic patients. A preliminary study. *Spinal Cord* 1996; **34**: 684–90.
8 Dallmeijer AJ, van der Woude LHV, Hollander AP, Angenot ELD. Physical performance in persons with spinal cord injuries after discharge from rehabilitation. *Med Sci Sports Exerc* 1999; **31**: 1111–17.
9 Dallmeijer AJ, van der Woude LHV, Hollander AP, van As HHJ. Physical performance during rehabilitation in persons with spinal cord injuries. *Med Sci Sports Exerc* 1999; **31**: 1330–35.
10 Duffill J, Buckley J, Lang D, Neil-Dwyer G, McGinn F, Wade D. Prospective study of omental transposition in patients with chronic spinal injury. *J Neurol Neurosurg Psychiatry* 2001; **71**: 73–80.
11 Dunkerley AL, Ashburn A, Stack EL. Deltoid triceps transfer and functional independence of people with tetraplegia. *Spinal Cord* 2000; **38**: 435–41.
12 Duran FS, Lugo L, Ramirez L, Lic EE. Effects of an exercise program on the rehabilitation of patients with spinal cord injury. *Arch Phys Med Rehabil* 2001; **82**: 1349–54.
13 Findley TW, Agre JC. Ambulation in the adolescent with spina bifida. II. Oxygen cost of mobility. *Arch Phys Med Rehabil* 1988; **69**: 855–61.
14 Gans BM, Haley SM, Hallenborg SC, Mann N, Inacio CA, Faas RM. Description and interobserver reliability of the Tufts Assessment of Motor Performance. *Am J Phys Med Rehabil* 1988; **67**: 202–10.
15 Gouvier WD, Cottam G, Webster JS, Beissel GF, Wofford JD. Behavioral interventions with stroke patients for improving wheelchair navigation. *Int J Clin Neuropsychol* 1984; **6**: 186–90.
16 Haley SM, Ludlow LH, Gans BM, Faas RM, Inacio CA. Tufts assessment of motor performance: an empirical approach to identifying motor performance categories. *Arch Phys Med Rehabil* 1991; **72**: 359–66.
17 Haley SM, Ludlow LH. Applicability of the hierarchical scales of the Tufts Assessment of Motor Performance for school-aged children and adults with disabilities. *Phys Ther* 1992; **72**: 191–202; discussion 202–206.
18 Harvey LA, Batty J, Fahey A. Reliability of a tool for assessing mobility in wheelchair-dependent paraplegics. *Spinal Cord* 1998; **36**: 427–31.
19 Hutzler Y. Physical performance of elite wheelchair basketball players in armcranking ergometry and in selected wheeling tasks. *Paraplegia* 1993; **31**: 255–61.
20 Janssen TWJ, Van Oers CAJM, Van der Woude LHV, Hollander AP. Reliability of heart rate responses to non-steady-state activities of daily living in men with spinal cord injuries. *Scand J Rehabil Med* 1994; **26**: 71–78.
21 Janssen TWJ, van Oers CAJM, Veeger HEJ, Hollander AP, van der Woude LHV, Rozendal RH. Relationship between physical strain during standardised ADL tasks and physical capacity in men with spinal cord injuries. *Paraplegia* 1994; **32**: 844–59.
22 Janssen TWJ, van Oers CAJM, Rozendaal EP, Willemsen EM, Hollander AP, van der Woude LHV. Changes in physical strain and physical capacity in men with spinal cord injuries. *Med Sci Sports Exerc* 1996; **28**: 551–59.
23 Jebsen RH, Trieschmann RB, Mikulic MA, Hartley RB, McMillan JA, Snook ME. Measurement of time in a standardized test of patient mobility. *Arch Phys Med Rehabil* 1970; **51**: 170–75.
24 Kirby RL, Lugar JA, Breckenridge C. New wheelie aid for wheelchairs: controlled trial of safety and efficacy. *Arch Phys Med Rehabil* 2001; **82**: 380–90.
25 Kirby RL, Swuste J, Dupuis DJ, MacLeod DA, Monroe R. The Wheelchair Skills Test: a pilot study of a new outcome measure. *Arch Phys Med Rehabil* 2002; **83**: 10–18.
26 Lehmann JF, Warren CG, Halar E, Stonebridge JB, DeLateur BJ. Wheelchair propulsion in the quadriplegic patient. *Arch Phys Med Rehabil* 1974; **55**: 183–86.
27 Mattison PG, Hunter J, Spence S. Development of a realistic method to assess wheelchair propulsion by disabled people. *Int J Rehabil Res* 1989; **12**: 137–45.
28 Mizukami M, Kawai N, Iwasaki Y *et al*. Relationship between functional levels and movement in tetraplegic patients. A retrospective study. *Paraplegia* 1995; **33**: 189–94.
29 Panikoff LB. Recovery trends of functional skills in the head-injured adult. *Am J Occup Ther* 1983; **37**: 735–43.
30 Schnelle JF, MacRae PG, Ouslander JG, Simmons SF, Nitta M. Functional Incidental Training, mobility performance, and incontinence care with nursing home residents. *J Am Geriatr Soc* 1995; **43**: 1356–62.
31 Schnelle JF, MacRae PG, Giacobassi K, MacRae HSH, Simmons SF, Ouslander JG. Exercise with physically restrained nursing home residents: maximizing benefits of restraint reduction. *J Am Geriatr Soc* 1996; **44**: 507–12.
32 Simmons SF, Schnelle JF, MacRae PG, Ouslander JG. Wheelchairs as mobility restraints: predictors of wheelchair activity in nonambulatory nursing home residents. *J Am Geriatr Soc* 1995; **43**: 384–88.
33 Taricco M, Colombo C, Adone R, Chiesa G, Di

Carlo S, Borsani M *et al.* The social and vocational outcome of spinal cord injury patients. *Paraplegia* 1992; **30**: 214–19.
34 Taricco M, Apolone G, Colombo C, Filardo G, Telaro E, Liberati A. Functional status in patients with spinal cord injury: a new standardized measurement scale. Gruppo Interdisciplinare Valutazione Interventi Riabilitativi. *Arch Phys Med Rehabil* 2000; **81**: 1173–80.
35 Vanlandewijck YC, Daly DJ, Theisen DM. Field test evaluation of aerobic, anaerobic, and wheelchair basketball skill performances. *Int J Sports Med* 1999; **20**: 548–54.
36 Webster JS, Cottam G, Gouvier WD, Blanton P, Beissel GF, Wofford J. Wheelchair obstacle course performance in right cerebral vascular accident victims. *J Clin Exp Neuropsychol* 1989; **11**: 295–310.
37 Webster JS, Rapport LJ, Godlewski MC, Abadee PS. Effect of attentional bias to right space on wheelchair mobility. *J Clin Exp Neuropsychol* 1994; **16**: 129–37.
38 Webster JS, Roades LA, Morrill B *et al.* Rightward orienting bias, wheelchair maneuvering, and fall risk. *Arch Phys Med Rehabil* 1995; **76**: 924–28.

Appendix – Search strategy

#1	mobility and wheelchair
#2	#1 and skill*
#3	#1 and task*
#4	#1 and measurement*
#5	#1 and test*
#6	#1 and ADL
#7	#1 and functional*
#8	#1 and instrument*
#9	#1 and performance
#10	#1 and clinimetrics
#11	#1 and psychometrics
#12	#1 and pathology
#13	#1 and behaviour
#14	#1 and activit*
#15	#1 and disabilit*
#16	#1 and assessment
#17	#2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16